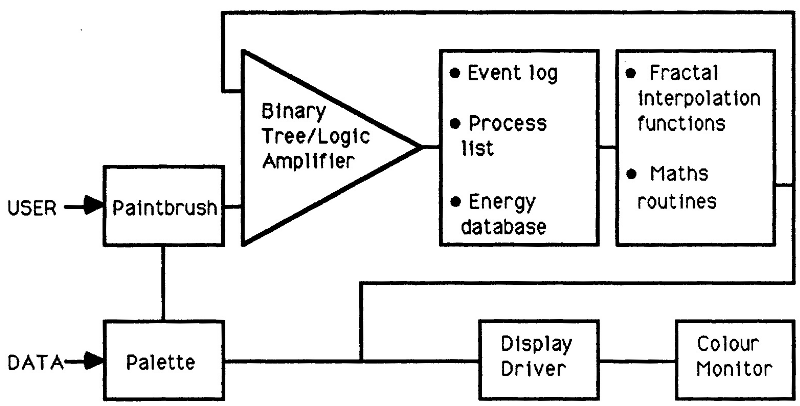
David Hawkins Research

Forensic Economics
Mentoring Communities
Virtual Prototyping and A.I.

DCM-004: The following document is a patent application for the Fractal Paintbrush. Derived from the Deductive Computing Machine (DCM), for the Fractal Paintbrush has application to problems of visual logic, the laws of physics and virtual prototyping. Both the Fractal Paintbrush and the DCM were invented by David Hawkins.

Virtual Prototyping with the Fractal Paintbrush



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CONTENTS

System and Method for Handling Data

The present invention relates to a system and method for handling data, and in particular to the object-oriented generation, analysis and / or validation of data within a computer. The method and system are based on those disclosed in European Patent Application 0369695, the contents of which are hereby incorporated by reference. The present description concludes with a g1ossary, which supplements the Glossary of the earlier application.

In particular the invention relates to the generation analysis and validation of data such as geological data from an oilfield to generate and justify quantitative descriptions of permeability, permeability continuity and hydrocarbon distribution in permeable rock. As with the earlier application, the use of a deductive computing machine (i.e. employing causal implication) provides absolutely certain conclusions.

In the article "Stochastic Modeling", (Journal of Petroleum Technology April 1990, Vol. 42, No. 4 pp 404-412) there is disclosed a method of the hybrid modeling of oil reservoirs. This poses the problem of combining a discrete model and a continuous model of a reservoir. The present invention seeks to provide a system and a method to solve this problem.

According to a first aspect of the present invention there is provided an object-oriented fractal imaging system comprising a logic amplifier having a first input which receives premises about objects from graphic means, a knowledge database, an interpolator incorporating a fractal interpolation functions database and display means, the output of the interpolator being connected to the display means and to a second input of the logic amplifier.

An advantage of the above system is that it can be used as an object-oriented computerised paintbox to generate, describe, analyse, manipulate and display images of computer-based objects and by visual comparison with images of real objects, validate the data from those real objects.

In a preferred system the objects are real objects, the graphics means comprising a computerised paintbrush associated with a computerised palette, the palette having a data input for data from a real world object, and the paintbrush selecting a sub-set of those data, wherein the feedback connected between the output of the interpolator and the second input of the logic amplifier tends to maintain a truth condition of matching the selected input data from the paintbrush with the output data from the interpolator whereby the display on the display means then represents real object data from the palette together with data from the interpolator.

The display means is preferably a colour monitor controlled by a display driver. Premises about an object can be entered in a window of the colour monitor.

An advantage of this system is that it is automatically constrained to obey the laws of physics. It enables the calculation of the truth value of displayed data from a real world object by visual comparison with data having the same colour assignments from a computer-based object.

The logic amplifier preferably comprises a binary energy tree, whereby the truth functional connectives "." and "v" are applied to premises about the real world.

The advantage of the use of an energy tree which is binary is that it facilitates analysis of input data; one knows that at any node which is true everything which is not the first of its daughter nodes must be the other daughter node and therefore can be logically identified.

The energy tree preferably has a parent node representing the space within a frame of reference and a pair of daughter nodes representing objects which are respectively mobile and immobile within and with respect to the frame of reference of the parent node.

Each daughter node may have respective pairs of further nodes. For example the "mobile" node may have nodes representing "moving" and "by-passed" objects; the "immobile" node may have nodes representing "solids" and "non-solids". When interpreting oil reservoir data, the "moving" objects may be sub-divided into "moving oil" and "moving non-oil" nodes and the "solids" node may be divided according to whether or not they are caused by pore lining.

In accordance with an alternative embodiment in which the objects are not wholly-real objects, the graphics means comprises a computerised paintbrush associated with a computerised palette, the palette having a data input for data - which is not wholly restricted to real objects, whereby the display on the display means is not restricted to reality.

This system permits unreal objects to be displayed, e.g. objects which pass through each other; this provides a very flexible graphics facility. For example an image of a real object may be treated as an unreal object to permit an imaginative animation effect to be created.

The present invention also provides a method of object-oriented generation, analysis and/or validation of data employing a system as set out above, wherein an object is assigned a unique colour by means of the computerised palette and also a truth value (true or false) by means of the computerised paintbrush.

In one preferred method events are described and logged by assigning to each of them, firstly, an index number in the order in which the event is believed to have occurred and, secondly, the time at which the event is believed to have occurred which is symbolised by the truth functional connective "$\supset$".

The event may be the deposition of a geological layer, which permits oilfields to be studied.

In a preferred method the fractal interpolation functions are used to render the energy tree visually on the display means whereby the fractal dimensions of value 0 to 1 give the probability of an identified node of the energy tree being true, 1 to 2 give the

directions of lines, 2 to 3 give the textures of surfaces, and 3 to 4 the shape of objects in the frame of reference

This enables a user to describe his intuitions about how densely a fractal occupies the metric space in which it lies.

Preferred embodiments of the present invention will now be described, by way of example only, with, reference to the accompanying drawings, of which:

Fig. 1 shows a system in accordance with the invention comprising a deductive computing machine;

Fig. 2 shows a binary energy tree, the parent node of which represents the energy space within a frame of reference selected by the user;

Fig. 3 shows diagrammatically an oilfield of which an integrated geological interpretation is to be constructed using a method and system in accordance with the present invention;

Fig. 4 shows respective density logs from the wells of the oilfield of Fig. 3;

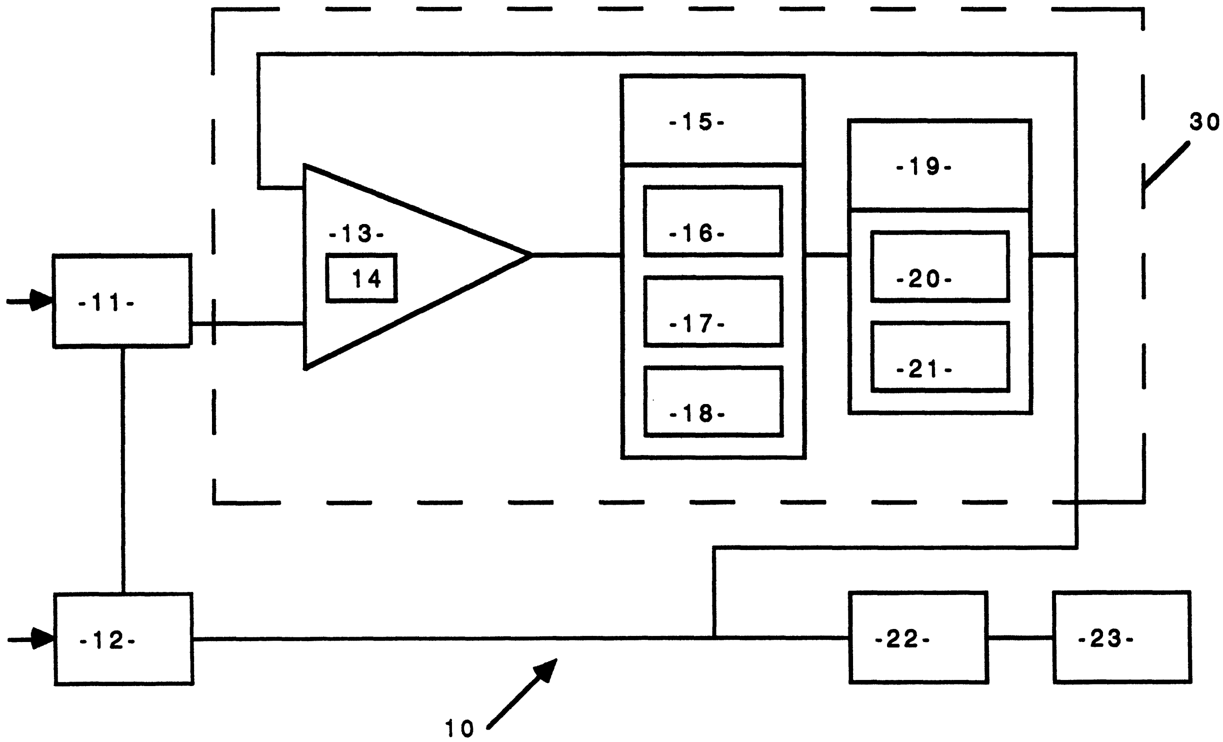
Fig. 5 shows the general flow path of a particle of oil through permeable rock;

Fig. 6 shows a binary energy tree relating to the flow path of Fig. 5;

Fig. 7 shows a binary energy tree relating to pore lining; and

Fig. 8 is a diagram relating to the movement of oil.

Figure 1



Referring to the drawings, Fig. 1 shows a system comprising a deductive computing machine 30 as disclosed in European Patent Application 0369695 except that for the user input there is substituted a computerised paintbrush 11 associated with a computerised palette 12, that the energy tree 14 is of a particular type, and that the interpolation functions database 20 contains fractal interpolation functions. These differences will now be explained.

The energy tree 14 is shown in Fig. 2 having a data structure which is a binary tree with the parent node being an AND-node which, in turn, has a daughter node and a terminal node. The daughter node represents the energy space which could contain compositions free to move (mobile) with respect to a frame of reference.

Figure 2

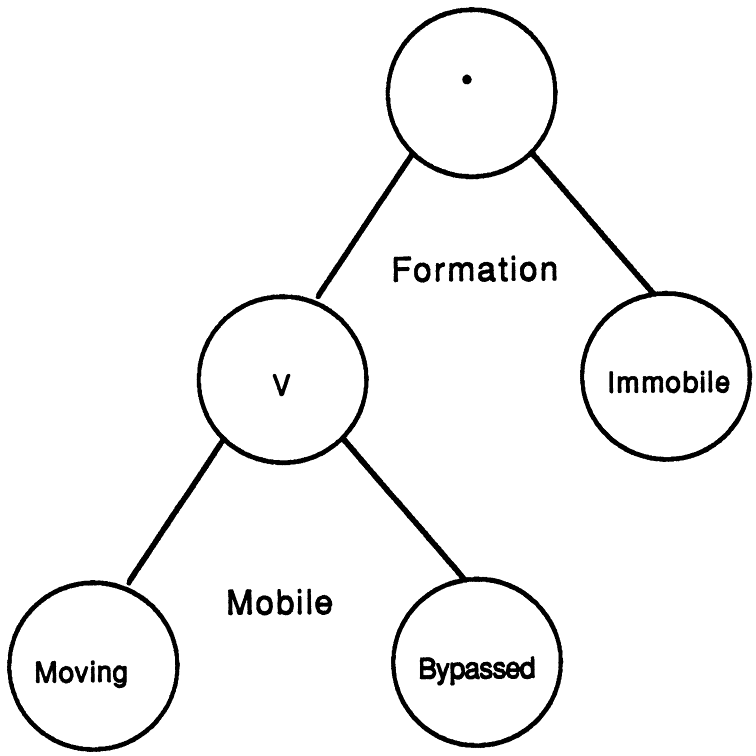


Figure 2.

The terminal node represents the energy space which contains compositions which are not free to move with respect to the frame of reference (immobile).

The daughter node which represents mobile compositions is represented by an OR-node link with two terminal nodes. The first of these nodes represent the compositions which are moving with respect to the frame of reference at a particular time, and the second node represents the compositions which are mobile but stationary with respect to the frame of reference (by-passed) at the same moment in time.

Associated with each node of this energy tree is a conditional probability (P) which corresponds to the probability of a node being true if its parent is true, or to the fractional volume of space occupied by that particular node, or to the fractional length of time spent in the node by a point moving randomly in the space of its parent node. If the parent node has volume V, the daughter node has volume P x V.

A general graphics mode of operation of the paintbrush 11 will now be described with reference to a computer paintbox system corresponding broadly to the system of Fig. 1 with the exception that there is no restriction on the input to the computerised palette 12, i.e. it does not need to relate to the real world. The palette is connected to a display driver 22 which drives a colour monitor 23. A paintbrush 11 is connected to the palette

12 so that any colour can be selected from the palette and displayed on the monitor. The output of the paintbrush is connected to an interpolator 19 which comprises an interpolation functions database and maths routines 21. The output from the interpolator is connected to the display driver 22. In the general graphics mode, the interpolations functions database 20 is loaded with a set of fractal interpolation functions, which relate the colour of the object to be painted with the position of the brush on the monitor at a time t, and the width of the brush selected.

The values of the fractal dimensions can be calculated to render visible with the maths routines 21 the action of the paintbrush and those values rendered visually on the monitor 23.

For example a brush stroke across the screen with blue paint could render a rough-textured, saw-tooth patterned object according to the fractal interpolation functions held in the database for the surface texture of objects of the colour blue and their interpolated directions relative to the blue paint stroke. Again, the user could select red objects to paint a pattern of red rings on top of the blue base and experiment with possible fabric designs. Animation is possible if the fractal functions contain time as an independent variable.

Four ranges of fractal numbers could be evaluated.

0-1 to describe the probability of existence of a colour at a point or node. Thus, if an air brush effect was required to 'dust' a blue surface with yellow, a low value, close to zero, would be used. Smudging could be avoided by making the probability of yellow on a plain background equal to 0.

1-2 to describe the direction of displayed lines relative to the direction of movement of the brush.

2-3 to describe the texture of a surface.

3-4 to describe the shape of an object.

An advantage of the above-described system is that it enables the user to paint a computer-based object with more dimensions than just colour and location. However, the lack of "real world object" constraints on the data input to palette 12 means the user is free to build a knowledge database 15 and interpolator 19 and thus to create objects which have no meaning in the real world. A user is free to create unreal objects, e.g. ones which pass through each other.

Returning now to Fig. 1 itself, this shows a system which is employed for object-oriented painting of only those objects which could exist in the real world. By attempting to maintain the truth condition of matching real world input data to the computerised palette 12 with output data from the interpolator 19 , the system models only objects which could exist in the real world.

The deductive computing machine is preferably as described in European Patent Application 0369695 with the modifications outlined above. In particular there is provided an improved binary data structure for the superior nodes of the energy tree 14 which here describes formations as made up of immobile, mobile, moving or by-passed compositions with respect to some frame of reference. A paintbrush is substituted for the user input 11, and a palette for data input 12, and fractal interpolation functions are stored in the interpolation functions database 20.

The event log 16 records all the information asserted as true required to define an event: the cause and the effect compositions as described on the energy tree; the time of the event and, through an index number, the order of the event in a sequence of events. The shape (SH) of any volume is the effect of a sequence of events which may involve compositions in splits, joins or adoptions. These events, in turn, require the creation, destruction or variation of surfaces (SUs) which can be called "event surfaces". The event log 16 will therefore record and index into a time sequence, all the event surfaces which define the shape of an object. The event log would then have the form of a linear-array linked list in which the event surfaces are indexed in order of occurrence, and the index number increases with time.

Two surfaces intersect at a line L so, in turn, each line can be indexed or named by the event surfaces which created it. Similarly, two lines intersect at a point PT which again can be indexed or named by the lines which created it.

If the energy tree of Fig. 2 is used to describe a particular object, such as an oilfield, then the most important event surfaces are those which are formed by the intersection of the mobile and immobile compositions. Thus, if Pmobile = 1 the parent composition is being described at a point in space and time where the composition is mobile with respect to the frame of reference. If Pimmobile = 1, the point is immobile with respect to the frame of reference. If Pmobile = 0, nothing can move with respect to the frame of reference of the parent node unless an event (split) occurs in which case material is free to move into the space previously immobile with respect to the frame of reference.

The process list 17 contains a user-specified set of processes to drive a simulation, the output of which may be recorded via feedback to the event log 16. Simulated events are driven by variations in the values of bound and free energy over time at the nodes of the energy tree. The knowledge database 15 can contain processes described in a number of different ways, for example -

"Increased compaction causes a reduction in mobile compositions"
- would allow the user to assert compaction and deduce/simulate a decrease in Pmobile.

Alternatively, an algorithmic description of the density of a composition describes a process which can be used for simulation purposes. Thus:

$$D_1 = \text{Pmobile} \times D_2 + (1-\text{Pmobile}) \times D_3$$

where D_1 is the density of the parent composition

D_2 is the density of the mobile composition, and

D_3 is the density of the immobile composition.

If the measured density D_1 of the parent composition is selected by the user and asserted as true and the density of the terminal compositions are known from the energy database 18, then Pmobile can be calculated by interpolation to generate a simulated value of D_1, to match the measured value of density. The simulation can therefore be driven by a premise from the paintbrush when the user selects and asserts that values, such as the values of the density log of an object, are "true" in the active windows selected by the user.

The energy database 18 is in the form of a linear array-based linked list and includes parameters already loaded into the knowledge database such as the density of a named compositions (e.g. oil). If that composition is asserted as true of the real world object then the associated parameter can be inserted with others into the relevant process equations to run the simulation. The simulation stops when the calculated value of density feed back to the second input of the logic amplifier equals the value of the density at the first input so validating that input value.

The system 10 -creates and/or visualises objects constrained to obey the laws of physics by using a computerised paintbrush 11 and palette 12. The output of the paintbrush is fed as a series of premises to a first input of the logic amplifier 13. The deductive computing machine maintains the truth values of the premises, constrains them to follow the same physical laws as their real world counterparts, and generates a simulation to, be rendered visually by the paintbrush.

Since the interpolator 19 contains fractal functions in the interpolation functions database 20, the monitor 23 can display the probability of identified energy nodes/points being true at particular locations, the direction of lines, the texture of surfaces and the shape of volumes. Interpolation between energy-tree event surfaces in time, for example, can now be rendered in space to give a 4-dimensional (3 space, 1 time) simulation on the monitor of the physical system to be modelled. The negative feedback loop from the output of the interpolator to a second input of the logic amplifier 13 allows the user to drive the simulation on the monitor until this simulation is inferred as a good match with the data input from 12. The computer based object has then been conditioned to match the measured and observed data and those parts of the object space for which no data is available have been rendered visually by the interpolator. The user can then see if his intuitions about the packing density of the fractals are confirmed by the appearance of the object in the colour monitor 23.

When the user infers a match with all the real world object data however, the data structure of the energy tree, knowledge database and interpolator corresponds to a fully parametrised model of the real world object.

A description of this model, from the event log 16 therefore corresponds to a possible interpretation or analysis of the real world object data. Without a match inferred, a description of the model is an invalid interpretation of the real world data.

The system of Fig. 1 may be employed to construct an integrated geological interpretation of an oilfield which is shown diagrammatically in Fig. 3. Three wells 70, 71 and 72 have been drilled through cap rock 73 into an oil reservoir 74 and on into the base 75 of the reservoir. Numeral 74 represents oil in porous rock, whereas numeral 79 represents water in porous rock. Wells 70 and 71 cross the oil/water contact surface 76. Wells 70, 71 and 72 have been cased, cemented and perforated in order that water can be injected into wells 70 and 71 in order to force oil out of well 72.

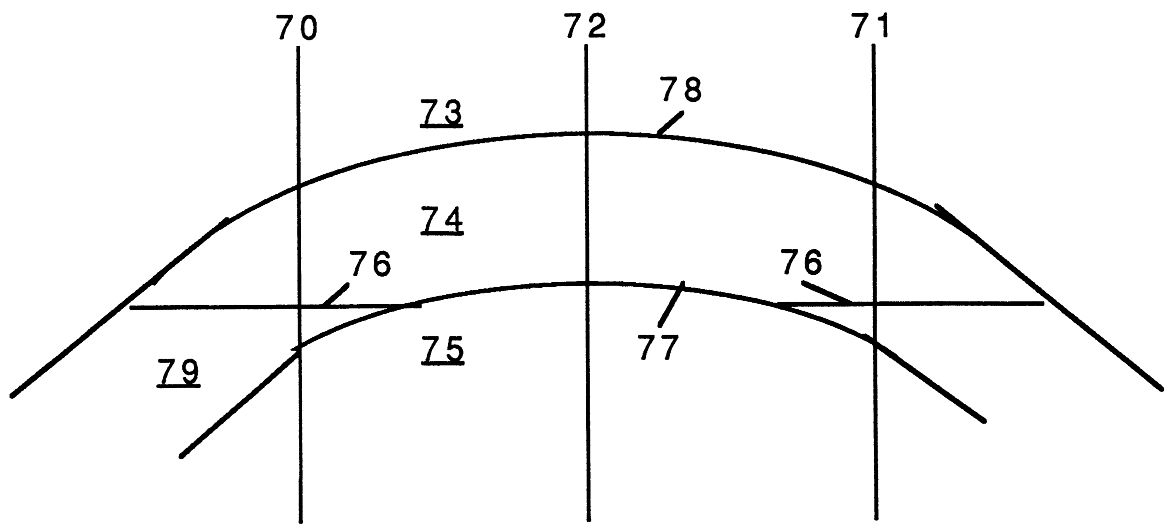
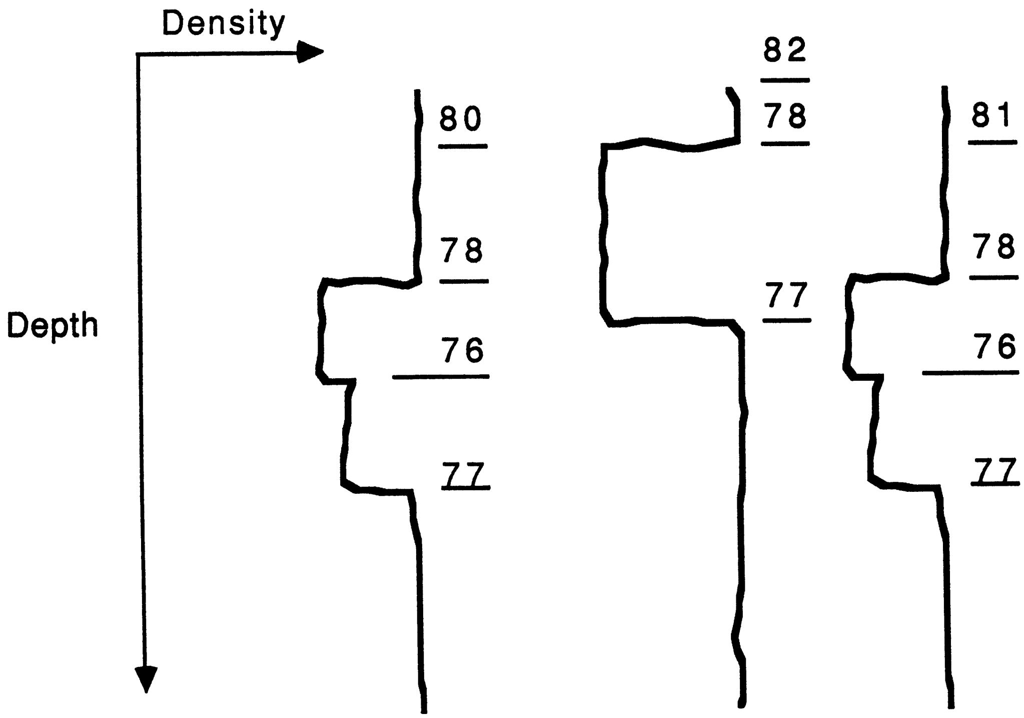


Figure 3

A geologist has for example available as input data to the palette 12: logs which are records of measurable parameters such as density, Fig. 4, or resistivity against depth; descriptions and photographs of core samples, which are samples of rock formation brought out of the well; seismic data which show acoustic reflections against time from subsurface formations; and records of pressure and flow rates over time, from surface and subsurface instruments as the field is produced.

Figure 4



The user assigns colours to the various identified object data types, by means of the computerised palette 12. The monitor 23 shows these colour assignments by adding to the colour icon the name of the data type to which it has been assigned. The user dips the computerised paintbrush 11 in the palette colour icon named "grid" and so asserts the grid is true in the window selected. The grid lines of the space within which data is to be interpreted, then appear from simulation and interpolation. When complete, the user will see in the selected colour a grid which bounds the space to be interpreted. The premise "formation is true" is then entered at the first input to the logic amplifier 13 by assigning a probability to the parent node of the energy tree. The event log 16 records the name of the object created, the event of creation itself (the conditional probability of "formation" changing from 0 to 1), index numbers for the event surfaces for this "formation" in the order in which they were asserted, the time and date that each surface was asserted, and any other relevant information, e.g. name of interpreter.

The event log 16 now holds a record of the user's creation of a computer-based object which is a formation assigned a colour within a grid of intersecting surfaces assigned another colour. Each event surface carries a sequential identification number and a time for the moment when each was asserted. By supplying the process list 17 with the sequence of locations for these event surfaces, the user can drive a simulation of the process by which an identified formation was created. The formation's frame of reference can be simulated by passing the spatial coordinates of each of its event surfaces to the interpolator 19 and displaying the associated lines of intersection with the stationary block surfaces on the monitor 23. Rendering all the lines and surfaces and

compositions (via' probabilities) with -the interpolator will generate a 4 dimensional image on monitor 23.

The process continues if the user then dips the paintbrush into a different object identified with another colour on the palette as "effective porosity" and so enters the premise "effective porosity is true" to the input of the logic amplifier 13. The event log 16 then records the name of the asserted composition "effective porosity", and index number(s) for the associated event surface(s) which are assigned to that composition in the order they have been asserted to occur.

Every well drilled in the formation block is an effect of the drilling process which causes "formation" compositions to take up an effective porosity with probability = 1, that is each well allows all material within the drilling event surface freedom of movement with respect to the stationary frame of reference of the formation block. Again, the knowledge database 15 and interpolator 19 are used to render a 4 dimensional simulation of wells of one colour being drilled into the formation block of another colour.

The user then tries to correlate logs 80, 81 and 82 (Fig. 4) from wells 70, 71 and 72. In this example, there are shown high density values for formations 73, 75 with no effective porosity and lower values for formations 79 containing mobile water and lowest values for formations 74 containing mobile water and oil.

The normal process of geologic interpretation then proceeds as follows

Browse data - look at all the relevant data from the field e.g. logs, seismic, and engineering data. Use the palette 12 to assign unique colours to identified data object types.

Interpret data - correlate the data (establish a mutual relationship); draw correlation sections to show these mutual relationships; draw structural cross sections: integrate seismic, log, engineering and other relevant data, and then construct a fourdimensional (3 space, 1 time) model of the field.

Objectives - To describe permeability (a measure of the ease of flow of one material through another e.g. oil through rock), permeability continuity (the connectivity of the space occupied* by the material which can move with respect to the other) and distribution of reservoir fluids, particularly hydrocarbons, in space.

With the improvements described herein, system 10 is operated as follows:

The user browses through data supplied at colour palette 12, and displayed on monitor 23 according to the selected colour codes. The data will be measurements or observations of compositions located in the selected frame of reference with coordinates of space and time.

Correlation of logs is the act of identifying events on logs in different wells which occurred at the same time in the same or similar energy spaces. Surface 77 in Figure 3

corresponds to the event when porous sediments settled on rock 75 with no effective porosity and so formed the base of the reservoir.

Surface 77 is intersected by the surfaces of wells 70, 71 and 72. Three lines are therefore generated which can be identified as L77/70, L77/71, L77/72. The system can show these lines in space because the well coordinates are known and the user, through correlation, has asserted that each line belongs to event surface 77.

The user now has on display a formation block (for which measured and observed data are available at palette 12) which is penetrated by wells displayed with a different colour and contains lines L77/70, L77/71 and L77/72 of yet another colour.

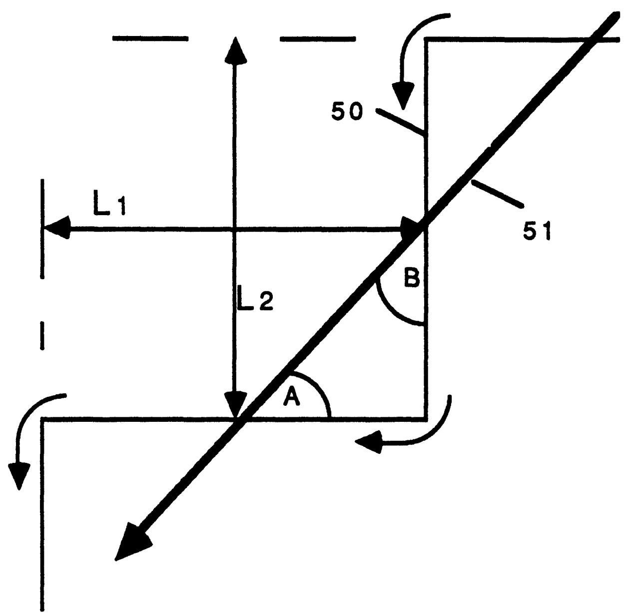
From an interpretation of the logs, formations with no effective porosity can be recognised. The paintbrush is dipped in the colour "immobile" and the process of identifying the mobile composition from its boundary event surface is continued and rendered in four dimensions on monitor 23 by use of the interpolator 19 to generate a surface connecting the lines L77/70, L77/71 and L77/72.

The external and internal shape of the reservoir is determined when all the event surfaces (which separate formations with no effective porosity from those with effective porosity) have been interpolated, visualised and accepted by the geologist.

Interpolation of compositions between the event surfaces (e.g. 78) which bound the compositions with effective porosity such as pore space, wells or perforations is effected by evaluating appropriate fractal interpolation functions 20. The probabilities and the flow paths of moving oil relative to a field pressure gradient require appropriate fractal interpolation functions to describe the characteristic metric space through which the oil flows.

To assert oil-bearing, continuously -permeable rock, the geologist paints some expected oil flow lines along estimated, maximum field gradients in the reservoir space. The paint brush picks up the "moving oil" colour and asserts it as "true" to the input of amplifier 13. The actual flow path can be rendered visible by interpolation of the values for the four fractal dimensions to give the conditional probability/volume of moving oil, its direction, surface textures and shapes. The actual flow path 50 of a particle of oil with respect to the asserted line 51 is shown in Fig. 5. The fractal interpolation function to describe the flow path will have to generate a path consistent with pore geometry; this is described below in more detail.

Figure 5



The branching lengths, L_1 and L_2 relate to properties of the material through which the oil is flowing and control the frequency of direction changes of the oil particles moving through the "immobile" colour. Angles A and B represent the relative direction of actual motion with respect to the asserted flow path. An equation of the form I = Ioe -µx could be expected to apply where I = oil Particles/sec passing through a section, distance x along the flow path from an original current strength jo. g is then an attenuation coefficient and x = 1/µ is the attenuation length over which the current strength falls to 1/e of the source. The number of changes of direction in a unit length of the flow path is $2/(L_1\cos A + L_2\cos B)$. The attenuation length must then be proportional to $1/2 (L_1\cos A + L_2\cos B)$.

The branching lengths and the angles A and B are formation properties determined by the energy history of the neighbourhood through which oil particles flow. This energy history is recorded in the event log 16 and the associated lengths and angles and probabilities derived from the process list 17 and energy database 18.

The way to extract most of the mobile oil is to try to align the maximum field gradient with the mid-points of the branch lengths. The effect of various geological processes on the attenuation length of a formation may be summarised as follows.

Transport

There are poorly sorted grains - A and B are randomly variable (and therefore frequently at right angles) with respect to any realistic maximum field gradient leading to a lower probability of moving oil.

Deposition

If there is only low energy and small grains in supply then small grains are deposited leading to short L_1 and L_2 and thus a short attenuation length; accordingly there is a lower probability of moving oil even if there is a preferential alignment of grains giving constant angles A and B.

Sediment Modification

Bioturbation means that angles A and B are variable making it impossible to align the field gradient with the direction of flows; again there is a lower probability of moving oil. Cementation shortens L_1 and L_2 also leading to a lower probability of moving oil.

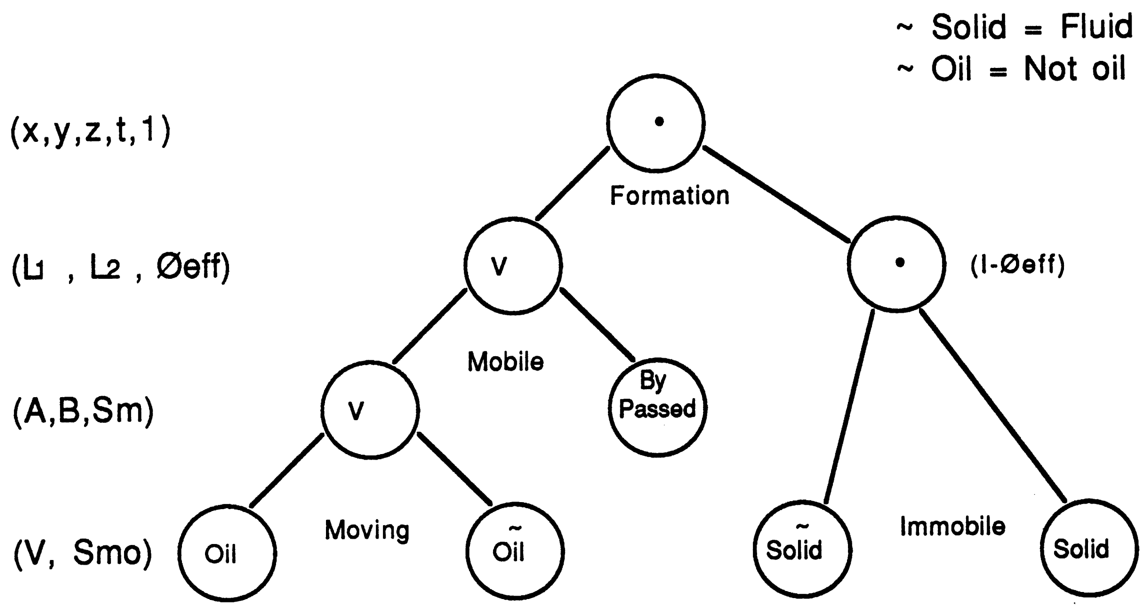
Compaction

This shortens L_1 and L_2 and, even if A and B are unchanged, therefore lowers the probability of moving oil.

Diagenesis

There are three related phenomena under this heading, i.e. pore plugging, grain coating and pore lining. In pore plugging, one or more crystals block an entire pore of the porous rock meaning that oil particles have to change direction more often to by- pass the plug; thus the rock is more impermeable and the attenuation length decreases. In grain coating, the surface of grains of the rock are coated with- a thin skin of crystals. In pore lining, "fingers" of crystals grow across the pore space reducing the porosity without completely blocking the pore. Pore plugging and grain coating shorten L_1 and L_2 and pore lining also varies A and B. Once more there is a lower probability of moving oil.

Figure 6



The geologist's asserted flow paths pass oil through compositions of different energy histories. The evolution of these formations can all be represented in the energy tree of Fig. 6. Each object's co-ordinates shown in brackets are derived from the knowledge database 15 and the interpolator 19.

The parent node of the energy tree represents a formation at rest with respect to a particular frame of reference and having coordinates x,y,z,t. Its daughter nodes represent the effective pore space of conditional probability Øeff .(having properties L_1 and L_2) and the non-porous part of the formation (l-Øeff). The symbols "v" and "." have the same meanings as disclosed in European Patent Application 0369695. The non-porous part in turn comprises fluids which are immobile under expected production conditions and solids.

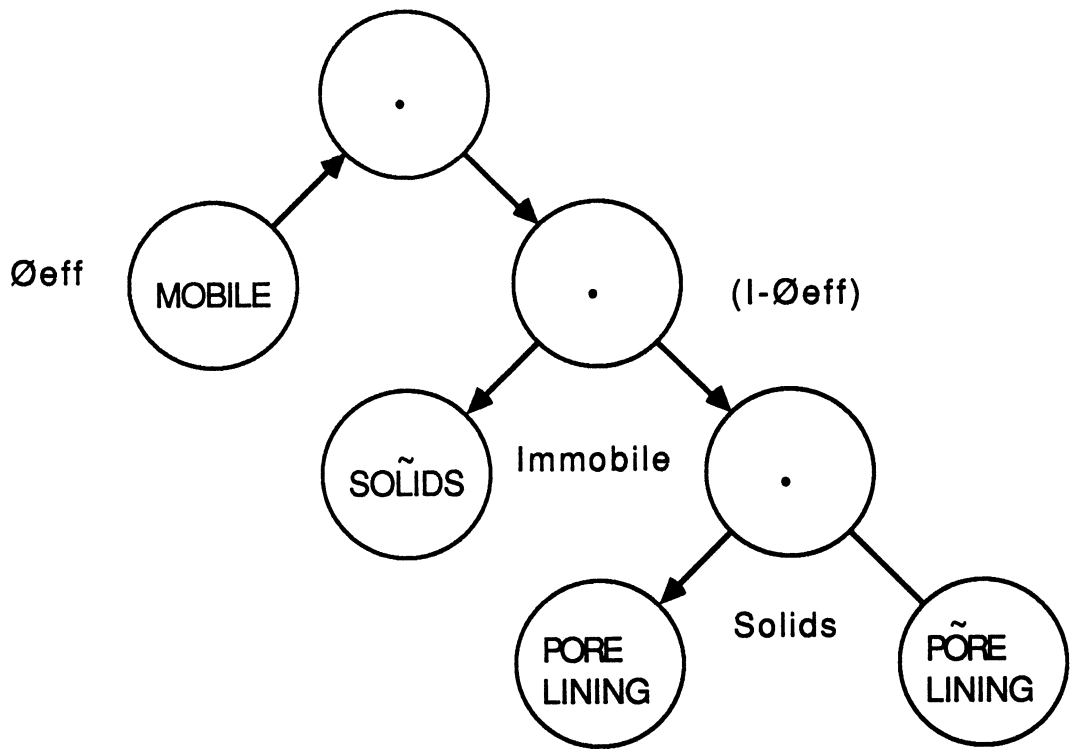
The value of conditional probability Øeff represents the probable proportion of mobile (i.e. movable) fluids within the formation. Øeff is in turn sub-divided into such fluids which are actually moving or are by-passed. Thus Sm is the proportion of mobile fluids which is actually moving and has properties A and B. The moving fluids contain oil or other fluids. The moving oil has a velocity V with respect to the frame of reference (N.B. The by-passed, mobile fluid is therefore moving at an equal and opposite velocity minus V with respect to the moving oil. Smo is the proportion of the moving fluids which is oil).

Thus the volume of moving oil in a unit volume of formation is 1 x Øeff x Sm x Smo. Thus the formation can be deduced as permeable reservoir rock if the product Øeff x Smo is greater than zero.

Application of- a sufficient, external field pressure gradient to the formation of Fig. 6 will cause oil particles to flow along the maximum internal gradient (the vector sum of all the external and the friction, viscous, capillary, gravitational and reaction forces which act on each particle of oil).

Assume the geologist asserts with a paintbrush 11 the truth of the colour "pore-lining" (where permeability is damaged by clay crystals lining the pores) in rectangular co-ordinates from a graphics based interpretation. The co-ordinates of the asserted flow path are known, so Øeff along the flow path (possibly as some function of L_1 and L_2) can be described and displayed from a fractal interpolation function. The energy tree represents pore lining effects as shown in Fig. 7 as caused by mobile material forming the pore lining crystals. If the knowledge data base 15 contains an assertion that "in pore-lined rock L_1 and L_2 are small and A and B are variable" then the system could evaluate Øeff and the fractional volume of moving oil to deduce that:

Figure 7



If Øeff = 0 then the volume of moving oil is:

Øeff x Smo, = 0

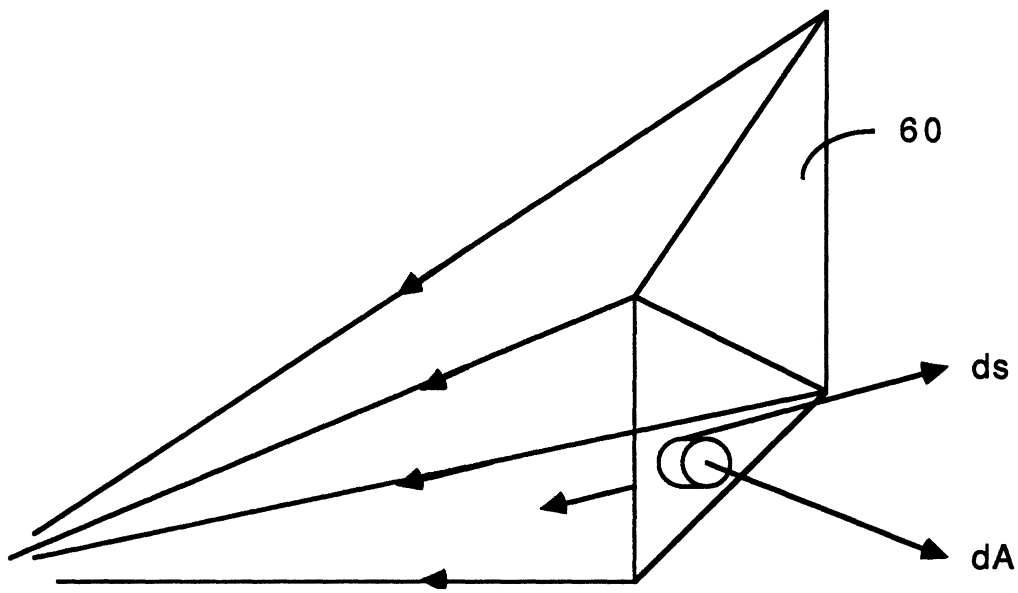
Therefore the flow path is false.

The geologist can then be advised that the flow path is false because it traverses an impermeable bed. If the next question is "Why is the bed impermeable", the system could identify/name the effect of Øeff = 0 and answer "pore lining". By rendering the

flow visible on monitor 23 the geologist can decide if the movement is consistent with his intuitions and knowledge of pore geometry and fluid behaviour.

A data structure for the production of oil from a reservoir will now be described with reference to Fig. 8.

Figure 8



Here 60 represents the event surface between injection fluid and moving oil, dA is an element of area in this event surface and ds is the distance moved by dA in time dt.

The geologist asserts key flow lines (maximum field gradients), thought most effective and realistic to drain the reservoir. The event log 16 records the time asserted for the first event surface (when injectant fluid enters the reservoir from well 71, say) and the time asserted for the last event when the same surface reaches the producing well, 72 and injectant enters well 72.

Process list 17 and energy database 18 contain information necessary for simulation i.e. processes from which measurable values e.g. density can be derived when conditional probabilities and component densities, viscosities, permeabilities etc are known.

If flow rates are asserted, or measured in the injecting or producing wells and if the viscosities of the fluids are known and if formation permeability is asserted by the geologist then the pressure drop at any moment between wells 71 and 72 along a flow path s can be calculated as

$$\int_{o}^{s} \frac{\text{flow rate x viscosity}}{\text{permeability}} \text{ x ds.}$$

Integrating the pressure gradient along any asserted flow path described by fractal interpolation functions gives the pressure drop between downhole injection points and production points. This drop can be measured and different flow paths interpolated until the simulated pressure drop equals the measured value and so validates that measured value at that moment in time.

The extent to which actual production reaches maximum recovery will depend on the success of the producer in maintaining the direction, magnitude and timing of the externally-applied pressure gradients to give the optimum flow paths and flow rates and minimise the chances of bypassing mobile hydrocarbons.

An advantage of the above-described data structure is that it can be used to generate and display an integrated geological interpretation. The data structure is defined as the set of intersections of flow paths (which describe the distribution of moving surfaces in time) with an energy tree (which describes the distribution of effective pore geometry in space). Interpolation in time along the flow path and interpolation of pore geometry in space will render visible on monitor 23 the injectant/oil surfaces in both space and time. Comparison with data from the real oilfield is continued until all relevant input data is validated by a match with simulated and interpolated data. A description of the data structure and contents of the event log 16 at the moment when all relevant data is validated, is a geologic interpretation of the oilfield.

Although described in particular relation to oilfield analysis, the invention can be applied in any desired field of study, including those mentioned in European Patent Application 0369695.

In a modification a real world object can be treated by the system as an unreal object so as to produce imaginative animation effects.

Glossary

Binary tree - tree in which each node has links to no more than two daughter nodes.

Window - an area on a display screen inside which a partial image of some object can be displayed. An active window is one where the input is directed as, for example, when window's contents are selected by putting a pointer or paintbrush into that window.

Feedback - the process of returning part of an output signal back to the input of a device. If feedback decreases the size of the input signal it is negative feedback.

Amplifier - a device which amplifies an input signal. A logic amplifier is a device which amplifies the truth value of an input statement. A logic amplifier with negative feedback will maintain the truth values of its output statement equal to the truth value -of its input statement i.e. it operates as a truth maintenance device.

Interpolate - make insertions between things. For example, between points to give lines, lines to give surfaces, surfaces to give compositions (or energy spaces) and events to give time.

Metric space - a set that contains members which can be evaluated from the same metric function.

Fractal interpolation functions- metric functions which generate the density with which the metric space between asserted things (e.g. points, lines, surfaces or events) are packed with the fractals of lines, surfaces, points or time respectively.

Object - oriented - describes a computer program which creates a data structure of data entities and data relationships which more or less resemble objects in the real world.

CLAIMS

1. An object-oriented fractal imaging system comprising a logic amplifier (13) having a first input which receives premises about objects from graphics means (11, 12), a knowledge database (15), an interpolator (19) incorporating a fractal interpolation functions database (20), and display means (22, 23), the output of the interpolator being connected tothe display means and to a second input of the logic amplifier.

2. A system according to claim 1 wherein the objects are real objects, the graphics means comprising a computerised paintbrush (11) associated with a, computerised palette (12), the palette having a data input for data from a real worldobject, and the paintbrush selecting a sub-set of those data, wherein the feedback connection between the output of the interpolator (19) and the second input of the logic amplifier (13) tends to maintain a truth condition of matching the selected input data from the paintbrush (11) with the output data from the interpolator (19) whereby the display on the display means (23) then represents real object data from the palette (12) together with data from the interpolator (19).

3. A system according to claim 2 wherein the logic amplifier (13) comprises a binary energy tree (14), whereby the truth functional connectives "." and "v" are applied to premises about the real world.

4. A system according to claim 3, wherein the energy tree (14) has a parent node representing the space within a frame of reference and a pair of daughter nodes representing objects which are respectively mobile and immobile within and with respect to the frame of reference of the parent node.

5. A system according to claim 1, wherein the objects are not wholly-real objects, the graphics means comprising a computerised paintbrush (11) associated with a computerised palette (12), the palette having a data input for data which is not wholly restricted to real objects, whereby the display or the display means (23) is not restricted to reality.

6. A method of object- oriented creation, analysis and/or validation of data employing a system according to any preceding claim wherein an object is assigned a unique colour by means of the computerised palette (12) and also a truth value (true or false) by means of the computerised paintbrush (11).

7. A method according to claim 6 wherein events are described and logged by assigning to each of them, firstly, an index number in the order in which the event is believed to have occurred and, secondly,

the time at which the event is believed to have occurred which is symbolised by the truth functional connective "$\supset$".

8. A method according to claim 6 or 7 when appended to claim 3 or 4, wherein the fractal interpolation functions (20) are used to render the energy tree (14) visually on the display means (23), whereby the fractal dimensions of value 0 to 1 give the probability of an identified node of the energy tree being true, 1 to 2 give the directions of lines, 2 to 3 give the texture of surfaces, and 3 to 4 the shape of objects in the frame of reference.

9. A method of describing and logging events by assigning to each of them, firstly, an index number in the order in which the event is believed to have occurred and, secondly, the time at which the event is believed to have occurred which is symbolised by the truth functional connective "$\supset$".

10. A method of object-oriented creation, analysis and/or validation of data employing a logic amplifier (13) having an energy tree (14), and an interpolator (19) including fractal interpolation functions (20) wherein the fractal interpolation functions (20) are used to render the energy tree (14) visually on the display means (23), whereby the fractal dimensions of value 0 to 1 give the probability of an identified node of the energy tree being true, 1 to 2 give the directions of lines, 2 to 3 give the texture of surfaces, and 3 to 4 the shape of objects in the frame of reference.

ABSTRACT

System and Method for Handling Data

In a system and method for the object-oriented generation, analysis and validation of data within a computer, an input of a logic amplifier (13) receives premises about objects from graphics means (11, 12), and the output of the logic amplifier is connected to a knowledge database (15) and an interpolator (19) incorporating a fractal interpolation function's database (20), the output of the interpolator being connected to display means (22, 23) and to another input of the logic amplifier. The logic amplifier (13) incorporates a binary energy tree (14). The system may handle data concerning real or unreal objects. Events can be described and logged by assigning to each of them, firstly, an index number in the order in which the event is believed to have occurred and, secondly, the time at which the event is believed to have occurred which is symbolised by the truth functional connective "$\supset$". The fractal interpolation functions (20) may be used to render the energy tree visually on the display means, whereby the fractal dimensions of value 0 to 1 give the probability of an identified node of the energy tree being true, 1 to 2 give the directions of lines, 2 and 3 give the texture of surfaces, and 3 to 4 the shape of objects in the frame of reference.

For further information **or to invite David Hawkins for a speech or workshop** on the Fractal Paintbrush, please contact:

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